NATIONAL BUREAU OF STANDARDS REPORT

PROGRESS REPORT

1966 EXPOSURE TEST OF NATURE-TONE ENAMELS ON STEEL

SUMMARY OF 6-MONTHS AND 1-YEAR INSPECTIONS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D. C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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PROGRESS REPORT
1966 EXPOSURE TEST OF NATURE-TONE ENAMELS ON STEEL
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by

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Sponsored by

Porcelain Enamel Institute

U.S. DEPARTMENT OF COMMERCE

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PROGRESS REPORT

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INTRODUCTION

The National Bureau of Standards and the Porcelain Enamel Institute have been conducting weathering tests of porcelain enamels since 1939 (1,2).[1/] The most recent test in this series was initiated in 1966 and consisted solely of Nature-Tone (matte) enamels on steel. The enamels included in this test have now been exposed for one year at three sites. This report summarizes the results of both the six-months and one-year inspections of these enamels.

A. Enamels Included in the Test

Twenty-five Nature-Tone enamels are included in this test. Twenty of these are the first twenty (101-120) colors selected by the Architects Advisory Council of the Porcelain Enamel Institute (see File No. 15-MI available from PEI) while the remaining five enamels were selected at random from colors submitted by the frit companies. These enamels were then prepared in both 4-7/16 inch square and 4 x 6 inch specimens by the five frit companies participating in this test.

B. Exposure Sites

Six specimens of each enamel are exposed at each of three sites. The 4 x 6 inch specimens are exposed on the International Nickel Company's racks at Kure Beach, North Carolina - 80 feet from the ocean. The 4-7/16 inch square specimens are exposed at the National Bureau of Standards Exposure site at Gaithersburg, Maryland, and at Miami, Florida by the South Florida Test Service at their tidewater site, which is one foot above high tide, thus subjecting specimens to salt spray but not immersion. In addition to the exposed enamels, three specimens of each enamel are kept in dark, dry storage. The specimens at Kure Beach are exposed at 30° to the horizontal while those exposed at South Florida and Gaithersburg are exposed at 45°.

C. High-Voltage Continuity of Coating Probe

One half of the specimens placed on exposure were selected on the basis that they pass the high-voltage continuity of coating probe. This was done to see if the high-voltage continuity of coating probe could be used to locate enamels with potential discontinuities that would permit the base metal to rust after the specimens had been placed on exposure. The probe voltages used were selected arbitrarily and are presented in Table 1.

[1/] Numbers in parentheses refer to Reference at the end of report.

INSPECTION PROCEDURE

A. Cleaning of Specimens

The specimens from all exposure sites were returned to the laboratory to be inspected after being exposed for six months and one year. Before proceeding with the inspection all specimens were cleaned by 1) scouring 30 strokes using a light pressure on a sponge that has been moistened with a one percent, by weight solution of trisodium phosphate and sprinkled with calcium carbonate, 2) rinsing with tap water, 3) rinsing with distilled water and 4) rinsing with alcohol. This cleaning procedure adequately cleaned the specimens exposed at all three sites.

B. Visual Inspection

After the above cleaning process, the specimens were examined visually for discontinuities as evidenced by either irridescent or rust colored spots.

C. Gloss and Color

The 45° specular gloss of the specimens was measured at four orientations near the center of the specimen. The gloss is reported as the percentage gloss retained after exposure. The initial gloss values are presented in Table 1.

The change in color was measured with a color difference meter. One of the three storage specimens of each enamel was used as the color standard to obtain the maximum efficiency possible with this type of instrument. The color change is reported as color retention which is 100 minus the color change in NBS units.

D. Protection of the Edges

The edges of the specimens were painted with two coats of paint before they were placed on exposure and an additional coat of paint was added after each inspection. This was done to prevent the edges (where enamel coverage is often light) from rusting and forming an irridescent film on the enamel surface which would affect the gloss and color measurements.

RESULTS AND DISCUSSION

A. Gloss and Color

The percentage gloss retained and the color retention for the enamels included in this test are given in Tables 2 and 3 respectively. Since the initial gloss of these enamels was low, small changes in the gloss values result in large percentage changes. Therefore, little emphasis is placed on the percentage gloss retained values.

Observation of the data in Table 3 would indicate that only one enamel (102) has changed color more than one NBS unit during the year's exposure. The change in color retention from 0 - 0.5 and 0.5 - 1 year given in Table 4 further indicates that the change in color retention has been reduced during the last six months exposure. If this trend continues, very little further color change in these enamels would be expected in the future.

B. Comparison of Nature-Tone Enamels with Enamels Included in the 1956 Exposure Test

The average gloss and color retained after one year's exposure for the acid resistant enamels on steel exposed at Kure Beach and Washington in the 1956 Exposure Test (2) are presented in Table 5. When these values are compared to those for the Nature-Tone enamels exposed at Kure Beach and Gaithersburg, it can be seen that the Nature-Tone enamels on steel have as good or better gloss and color retention as the older, glossy enamels.

C. Continuity of Coating

It was mentioned earlier that one half of the enamels exposed in this test were selected on the basis that they pass the high-voltage probe. The number of specimens that have rusted after six months' and one year's exposure in both the probed and unprobed groups are presented in Table 6. Here it can be seen that there is a definite reduction in the tendency to rust of enamels that have passed the high-voltage probe.

D. Comparison of Exposure Sites

A two-sided sign test (3) performed on the one-year data in Tables 2 and 3 indicated that there was no difference in severity of attack of the enamel when color was considered but all three sites differed significantly when gloss was considered. Again the rankings according to gloss are not considered significant because the initial gloss readings were so low.

Perhaps a better indication of the severity of attack of the enamels exposed at the different sites would be to observe the data in Table 6 and note that 22 specimens exposed at Kure Beach rusted and 15 specimens exposed at South Florida rusted while only one specimen exposed at Gaithersburg rusted after one year's exposure. This indicates that the environments at Kure Beach and South Florida are much more severe than at Gaithersburg.

SUMMARY

In summary it may be stated that the gloss and color retention of the Nature-Tone enamels on steel after one-year's exposure at Kure Beach, South Florida, and Gaithersburg are extremely good. However, the protective properties of these enamels are not quite as good as those provided by the older glossy enamels. However, it has been indicated that specimens with pinhole type defects which will permit corrosion of the base metal after very short exposure times can be located by the use of a high-voltage continuity of coating probe.

Table 5. Comparison of Gloss and Color Retention after One Year's Exposure of Nature-Tone Enamels on Steel with the Acid Resistance Enamels on Steel Included in the 1956 Exposure Test

Enamel	Color Retention		Percentage Gloss Retained	
	Kure Beach	Washington-Gaithersburg	Kure Beach	Washington Gaithersburg
ACID Resistant on Steel, 1956 Test	98.9	98.8	81.1	83.4
Nature-Tone on Steel 1966 Test	99.4	99.3	93.4	91.0

Table 1 . Summary of Initial Data for Enamels in the 1966 Exposure Test of Nature-Tone Enamels on Steel.

Enamel	45° Specular Gloss	Acid Spot Rating	Acid Solubility (mg/in^2)	Thickness (mils)	Continuity of Coating	
					Probe Voltage (kV)	Overvoltage (kV)
101	13.8	B	14.4	8.8	1.5	0.6
102	13.5	B	9.5	8.0	2.0	1.2
103	13.3	A	8.3	7.5	1.5	0.7
104	17.4	B	7.4	9.2	2.0	1.1
105	14.9	A	1.6	9.6	1.0	0.1
106	27.3	A	7.8	9.1	2.0	1.1
107	14.4	A	1.8	9.9	1.5	0.5
108	19.2	A	1.2	9.4	2.5	1.6
109	16.6	A	0.7	9.2	2.5	1.6
110	20.7	AA	0.8	9.0	2.0	1.1
111	18.5	A	1.0	10.8	2.5	1.5
112	13.5	A	0.9	10.7	2.0	1.0
113	10.1	A	1.0	10.8	2.5	1.5
114	15.0	A	1.0	8.8	2.0	1.1
115	9.3	A	0.9	10.6	2.5	1.5
116	16.8	A	0.9	9.9	2.5	1.5
117	20.7	A	2.4	8.7	2.0	1.1
118	14.7	A	2.4	10.2	2.5	1.6
119	27.7	A	3.9	9.4	2.5	1.6
120	21.2	A	0.7	9.2	2.0	1.1
1	24.4	A	2.6	9.0	2.0	1.1
3	20.5	A	3.0	9.6	2.5*	1.6
4	11.3	A	2.8	8.8	2.0	1.1
6	2.2	B	8.4	9.1	2.0	1.1
7	3.4	B	6.9	9.4	2.5	1.6

* All of the specimens exposed at South Florida and Gaithersburg passed the high-voltage probe at 2.5 kV, but the specimens exposed at Kure Beach passed the high-voltage probe at 1.5 kV.

Table 2. Summary of Percentage Gloss Retained Data for Enamels Exposed in the 1966 Exposure Test of Nature-Tone Enamels on Steel.

Enamel	Percentage Gloss Retained for the Various Exposure Times							
	Kure Beach		South Florida		Gaithersburg		Storage	
	6-Mos.	1-Yr.	6-Mos.	1-Yr.	6-Mos.	1-Yr.	6-Mos.	1-Yr.
101	85.48	84.58	93.70	90.35	87.46	92.78	103.15	102.43
102	82.59	76.59	89.10	85.85	82.15	76.77	102.52	102.31
103	90.77	88.91	96.23	90.60	91.49	84.92	99.54	99.22
104	89.89	83.48	98.14	99.34	98.48	89.07	102.61	100.19
105	87.53	87.18	93.71	89.21	90.70	84.99	103.58	101.95
106	88.40	83.33	95.98	90.58	90.11	81.86	105.03	99.78
107	88.98	84.98	93.63	90.16	90.11	83.83	100.67	98.65
108	102.09	97.78	101.64	99.62	94.05	96.17	102.54	99.95
109	104.81	100.45	101.67	97.77	103.62	99.10	102.78	100.12
110	103.18	101.88	102.04	93.34	102.11	98.04	103.66	100.13
111	99.78	94.97	102.24	99.69	92.29	90.36	103.43	101.91
112	101.45	102.71	104.55	102.62	101.68	101.39	101.97	100.46
113	105.26	104.86	107.33	105.72	102.45	99.82	107.33	100.37
114	89.22	89.12	94.93	92.09	91.37	87.04	99.68	98.54
115	91.60	89.86	97.54	93.58	94.96	87.76	95.43	97.71
116	93.06	90.95	97.36	94.04	92.49	87.91	99.08	95.97
117	87.14	84.44	90.19	87.08	87.42	83.39	101.75	99.04
118	93.85	92.82	94.67	93.69	95.04	86.48	94.53	94.17
119	90.04	86.60	96.77	93.06	92.45	85.31	102.92	100.88
120	93.40	88.76	99.52	96.06	92.46	86.58	101.45	97.81
1	86.42	82.42	93.00	88.02	91.33	84.89	102.34	99.41
3	88.04	85.00	94.19	88.34	90.48	82.48	103.78	100.52
4	89.23	85.88	92.31	89.24	87.47	80.63	87.39	99.04
6	145.22	142.66	151.69	144.70	133.73	139.82	108.51	138.85
7	127.25	125.02	132.54	129.96	109.95	112.50	110.15	125.36
Average	96.20	93.36	100.59	96.71	95.63	90.96	101.55	101.88

Table 3. Summary of Color Retention Data for Enamels Exposed in the 1966 Exposure Test of Nature-Tone Enamels on Steel.

Enamel	Color Retention for the Various Exposure Times							
	Kure Beach		South Florida		Gaithersburg		Storage	
	6-Mos.	1-Yr.	6-Mos.	1-Yr.	6-Mos.	1-Yr.	6-Mos.	1-Yr.
101	99.14	99.18	99.51	99.30	99.20	99.13	99.82	99.72
102	98.77	98.96	98.94	99.03	98.76	98.73	99.68	99.84
103	99.64	99.54	99.49	99.35	99.60	99.45	99.88	99.88
104	99.64	99.52	99.80	99.53	99.58	99.63	99.77	99.80
105	99.64	99.50	99.74	99.59	99.58	99.54	99.72	99.76
106	99.42	99.25	99.67	99.37	99.36	99.30	99.68	99.53
107	99.55	99.51	99.38	99.52	99.70	99.58	99.52	99.51
108	99.45	99.52	99.70	99.54	99.50	99.48	99.53	99.73
109	99.79	99.47	99.47	99.53	99.63	99.20	99.74	99.73
110	99.75	99.72	99.60	99.66	99.82	99.69	99.80	99.80
111	99.35	99.20	99.74	99.67	99.56	99.46	99.66	99.50
112	99.72	99.57	99.64	99.55	99.47	99.62	99.62	99.83
113	99.63	99.44	99.43	99.46	99.61	99.75	99.61	99.63
114	99.78	99.47	99.59	99.54	99.54	99.31	99.05	99.56
115	99.56	99.48	99.62	99.42	99.57	99.69	99.48	99.27
116	99.54	99.79	99.74	99.61	99.45	99.31	99.20	99.53
117	99.27	99.23	99.65	99.45	99.44	99.20	99.92	99.31
118	99.50	99.51	99.13	99.51	99.65	99.31	99.88	99.82
119	99.59	99.55	99.73	99.81	99.75	99.55	99.29	99.79
120	99.72	99.57	99.63	99.64	99.40	99.64	99.65	99.52
1	99.53	99.50	99.79	99.70	99.63	99.69	99.61	99.73
3	99.41	99.28	99.45	99.34	99.31	99.09	99.64	99.61
4	99.39	99.25	99.54	99.48	99.57	99.25	99.81	99.15
6	99.76	99.77	99.80	99.75	99.84	99.73	99.81	99.70
7	99.54	99.65	99.49	99.33	99.56	99.50	99.86	99.85
Average	99.52	99.42	99.57	99.48	99.52	99.49	99.66	99.62

Table 4 . Comparison of Color Change Occurring in the Enamels in the 1966 Exposure Test of Nature-Tone Enamels on Steel.

Enamel	Change in Color R tention							
	Kure Beach		South Florida		Gaithersburg		Storage	
	0-½ Yr.	½-1 Yr.	0-½ Yr.	½-1 Yr.	0-½ Yr.	½-1 Yr.	0-½ Yr.	½-1 Yr.
101	0.86	0.04	0.49	0.21	0.70	0.07	0.18	0.10
102	1.23	-0.19	1.06	-0.09	1.24	0.03	0.32	-0.16
103	0.34	0.12	0.51	0.14	0.40	0.15	0.12	0.00
104	0.34	0.14	0.20	0.27	0.42	-0.05	0.23	-0.03
105	0.34	0.16	0.26	0.15	0.42	0.04	0.28	-0.02
106	0.58	0.17	0.33	0.30	0.64	0.06	0.32	0.15
107	0.45	0.04	0.62	-0.14	0.30	0.12	0.48	0.01
108	0.55	-0.07	0.30	0.16	0.50	0.02	0.47	-0.15
109	0.21	0.32	0.53	-0.06	0.37	0.43	0.26	0.01
110	0.25	0.03	0.40	-0.06	0.18	0.13	0.20	0.00
111	0.65	0.15	0.25	0.12	0.44	0.10	0.34	0.16
112	0.28	0.13	0.36	0.09	0.53	-0.15	0.38	-0.21
113	0.37	0.19	0.57	-0.03	0.39	-0.14	0.39	-0.02
114	0.22	0.31	0.41	0.05	0.46	0.23	0.39	0.05
115	0.44	0.08	0.38	0.10	0.43	-0.12	0.52	0.21
116	0.46	-0.25	0.26	0.13	0.55	-0.25	0.80	-0.33
117	0.73	0.04	0.35	0.20	0.56	0.24	0.08	0.61
118	0.50	-0.01	0.87	0.36	0.35	0.31	0.12	0.06
119	0.41	0.04	0.27	-0.08	0.25	0.20	0.71	-0.50
120	0.28	0.13	0.37	-0.01	0.60	-0.24	0.35	0.13
1	0.47	0.03	0.21	0.07	0.37	-0.06	0.35	0.06
3	0.59	0.13	0.55	0.11	0.69	0.22	0.36	0.03
4	0.61	0.14	0.46	0.06	0.43	0.32	0.19	0.66
6	0.24	-0.01	0.20	0.05	0.16	0.11	0.19	0.11
7	0.46	-0.11	0.51	0.16	0.44	0.06	0.14	0.01

Table 6 . Effect of High-Voltage Probe on Sorting Enamels Susceptible to Early Rusting

Enamel	No. Rusted at Kure Beach				No. Rusted at South Florida				No. Rusted at Gaithersburg			
	Selected by High-Voltage Probe		Randomly Selected		Selected by High-Voltage Probe		Randomly Selected		Selected by High-Voltage Probe		Randomly Selected	
	6-Mos.	1-Yr.	6-Mos.	1-Yr.	6-Mos.	1-Yr.	6-Mos.	1-Yr.	6-Mos.	1-Yr.	6-Mos.	1-Yr.
101	0	0	1	1	0	0	1	1	0	0	0	0
102	1	1	1	1	0	0	1	1	0	0	0	0
103	3	3	3	3	0	0	0	0	0	0	0	0
104	0	0	1	1	0	0	2	2	0	0	0	0
105	1	1	2	2	0	1	0	1	0	0	0	1
106	0	0	0	0	0	0	1	1	0	0	0	0
107	1	1	2	2	0	0	0	0	0	0	0	0
108	0	0	0	0	0	0	0	0	0	0	0	0
109	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0
111	1	1	1	1	0	0	0	0	0	0	0	0
112	0	0	0	0	0	1	0	1	0	0	0	0
113	0	0	0	0	0	2	0	0	0	0	0	0
114	0	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	1	0	0	0	0
117	0	0	0	0	0	0	1	1	0	0	0	0
118	0	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	1	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	1	2	0	0	1	1	0	0	0	0
7	0	0	0	1	0	0	0	0	0	0	0	0
Total	7	8	12	14	0	4	7	11	0	0	0	1


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